AC 2009-1436: ENERGY AUDITS AND SUSTAINABLE ENGINEERING

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Energy Audits and Sustainable Engineering

Abstract

Undergraduate Engineering majors are introduced to Sustainable Engineering by conducting energy audits at farms, office buildings, and industrial facilities. These projects provide real world experiences where the students are called upon to use all their book knowledge, common sense and resourcefulness to make a significant contribution to project goals. Work is conducted in an experiential learning course required by the engineering curriculum. When appropriate, students also work outside of class for pay, e.g., during the summer. Students work in multidisciplinary teams. They are responsible for interacting with clients, conducting audit inventories, simulating building performance with computer models, making recommendations, producing engineering reports, and making presentations. Typical recommendations focus on lighting, equipment & appliances, and HVAC systems. Students also assess the appropriateness of solar energy at many sites. The projects introduce student to the triple bottom line, i.e., projects must work at environmental, economic, and social levels. Students determine the costs, savings and payback periods associated with their recommendations. Though done in a less formal manner, they also consider the appropriateness of their recommendations at a social level. The purpose of this paper is to describe the experiential education program that supports these activities, and evaluate the use of energy audits to teach students about sustainable engineering. Evaluations are based on observation and student deliverables.

Introduction

Undergraduate Engineering majors are introduced to Sustainable Engineering by conducting energy audits at farms, office buildings, and industrial facilities. These projects provide real world experiences where the students are called upon to use all their book knowledge, common sense and resourcefulness to make a significant contribution to project goals. Work is conducted in an experiential learning course required by the engineering curriculum. When appropriate, students also work outside of class for pay, e.g., during the summer. Students work in multidisciplinary teams. They are responsible for interacting with clients, conducting audit inventories, simulating building performance with computer models, making recommendations, producing engineering reports, and making presentations. Typical recommendations focus on lighting, equipment & appliances, and HVAC systems. Students also assess the appropriateness of solar energy at many sites. The projects introduce student to the triple bottom line, i.e., projects must work at environmental, economic, and social levels. Students determine the costs, savings and payback periods associated with their recommendations. Though done in a less formal manner, they also consider the appropriateness of their recommendations at a social level.

The purpose of this paper is to describe the experiential education program that supports these activities, and evaluate the use of energy audits to teach students about sustainable engineering. Evaluations are based on observation and student deliverables.
 Two energy audits are described in the paper: conducted for the Fort Dix National Guard Headquarters and the Atlantic County Utility Authority. Both are located in New Jersey.

Background

Our Engineering College is committed to innovative methods of learning to best prepare students for a rapidly changing and highly competitive marketplace [1]. Key objectives include:

- Creating multidisciplinary experiences through collaborative laboratories and coursework;
- Incorporating state-of-the-art technologies throughout the curricula;
- Creating continuous opportunities for technical writing and communication, and
- Emphasizing hands-on, open-ended problem solving, including undergraduate research.

To help meet these curriculum objectives, the four engineering programs have common Engineering Clinic classes (Clinics) throughout their programs of study. Students enroll in Clinics in each of their eight semesters at Rowan. Each clinic class involves students in teamwork (often interdisciplinary), hands-on activities, and report writing and presentation.

The Freshman Clinic is focused on engineering measurements (Fall) and competitive assessment (Spring). Fall lectures teach survival skills and other topics important to freshman engineers, such as note taking, problem solving, engineering judgment, and ethics. Laboratory components in the Fall introduce students to engineering concepts. In Spring clinic, students work on a semester-long competitive assessment project. Competitive assessment is the systematic testing of existing products, for the purpose of improvement and comparison. For example, students have assessed beer brewing, portable water filters, toothbrushes, and radios. Students are mixed from all four disciplines in their Freshman Engineering Clinic classes.

The Sophomore Clinic is focused on engineering design and communication. For perhaps the first time in their studies, students are exposed to realistic design problems best solved by multidisciplinary engineering teams. This course has significant communication components, both writing and speaking. Past projects include the design of landfills and baseball parks, the design and construction of guitar effect pedals and microbial fuel cells, wind turbines, and building energy audits. The course is team-taught with communications faculty. Where possible, students write about and give speeches related to their engineering work. Working together, Communications and Engineering faculty assess student work.

In Junior and Senior Clinics, students work in small teams of juniors and seniors on open-ended projects under the supervision of one or more professor. Each team works on a unique project, which can be multiple semesters in length. A typical sequence includes: information search and review; development of a clear and concise problem statement; research and/or design and testing activities; and presentation of results via written report and presentation. Projects have ranged from modeling bridges to demonstration of new site remediation technologies. Most projects are funded by industry or governmental agencies. Over 60 projects are run in a typical semester.

Experiential education involves educators teaching by engaging students directly in real experiences and focused reflection. Experiential learning is a component of experiential education, i.e., learning through direct experience. Experiential education and learning can be a valuable component of engineering courses [2,3,4,5,6]. Conducting Energy Audits for real

clients in Junior and Senior Engineering Clinic provides students with a quality experiential learning experience. Students define project scope, communicate with clients, conduct field assessments, assess data, write engineering reports, make recommendations, and give presentations.

Energy audits are conducted as part of the Rowan University Clean Energy Program [7]. Energy audits have been completed as part of Sophomore, Junior, and Senior clinic. Energy audits completed as part of Sophomore clinic have been described elsewhere [8,9]. Junior and Senior clinic audits tend to have more comprehensive expectations, less overall guidance, and require the students to manage the customer relation. Two energy audits completed as part of Junior and Senior clinic are presented here, of the Fort Dix National Guard headquarters building and the Atlantic County Utility Authority GEO and Operations buildings.

Fort Dix National Guard Headquarters Energy Audit

The Energy Audit of the Ft. Dix National Guard Headquarters comprised a full inventory of the energy-using devices within the building, as well as recommendations for reducing energy use. In addition, a Solar Panel layout design was generated using computer drafting and solar pathfinder analysis. These methods were used in an attempt to reduce total energy consumption to lower the building's monthly utility costs and carbon footprint. The audit was lead by a senior Civil & Environmental Engineering student and conducted by a team of engineering students from Civil & Environmental, Mechanical, and Electrical & Computer. All work was conducted by the students.

The Fort Dix National Guard Headquarters was built in the 1980's with a major addition completed in 1991. The total size is over 100,000 sq-ft with more than 200 employees. The structure is comprised of brick and masonry construction. The Headquarters is a multi-purpose establishment, used for communications, networking, teaching, meetings, storage, computer work-stations, and other jobs associated with the New Jersey National Guard. It is also open one weekend a month for the National Guard Reserves.

The audit began by establishing an inventory of all energy consuming devices associated with the building. This included all items that consume either electricity or natural gas. It was then possible to find the distribution of energy use throughout the premises. In addition, onsite environmental data relating to energy use (temperature, light intensity, relative humidity) was collected over a one week period, and a complete solar photovoltaic assessment of the rooftop was completed. A building energy model (Energy-10, Sustainable Buildings Industry Council and US DOE) was used to model HVAC components. The project resulted in detailed electricity and gas use inventories, recommendations to save up to 47% of the current energy consumption (approximately $117,000 per year), and a proposal for a photovoltaic installation for the New Jersey National Guard Headquarters Building.

Inventorying every energy-using object in a large building is no simple task. In this case, it began with the Spring 2008 Rowan University Clean Energy Clinic team of one dozen students. A handful of these students had previous experience with performing energy audits, from previous clinics. These took the lead in training the other students and creating spreadsheets and

protocols necessary to complete the job. During the first site visit, with the 12 students, almost every object in the building was cataloged and recorded in field notes. During this visit the students also set-up devices to obtain environmental data and longer-term (generally one week) electrical usage of certain appliances. After this job was done it was up to a sub-group of students to take the initiative and complete the audit.

During the Summer of 2008 students were employed to continue the work of the Rowan University Clean Energy Team. They were given multiple tasks throughout the summer that tested their engineering knowledge and ability to perform not only calculations, but also to plan work tasks, communicate with clients, write engineering reports and give presentations. The summer tasks began with data input to enter the large list of energy consuming devices into the spreadsheets. Throughout the building there was over 3,000 light bulbs and 200 computer workstations, and an HVAC system with over 50 components.

To understand many of the appliances and how much energy they used students were forced to combine knowledge from various engineering disciplines. This ability to cross disciplines will help the students be more versatile engineers. This also helps illustrate the effect that the Rowan University Clinics can have on students. By giving them the opportunity to work in multi-disciplinary teams, students learn skills that will carry over into the workplace.

The Fort Dix National Guard Headquarters Energy Audit was completed during Summer 2008 by the Rowan University Clean Energy Team. The audit created a spreadsheet model that was able to account for 99.5% of the 1,515,640 kWh used by the Ft. Dix National Guard Headquarters on an annual basis. Simulations performed using the spreadsheet identified energy saving options, including lighting retrofits and HVAC improvements. Based on the recommendations made, approximately 47% of the total energy, both electrical and natural gas, used in the building can be conserved. Examples of these recommendations include different types of lighting equipment, including ballast replacements, LED lighting, and occupancy sensors. Other recommendations included HVAC component replacement. Based on Energy-10 modeling, it appears that the HVAC system is significantly over-sized and inefficiently operated. The recommendations considered can be viewed in Table 2. The energy saving recommendation could result in an annual savings of $112,400 based on current utility pricing.

Table 1: Annual Savings and Payback Periods

Energy Conservation Method	Annual Savings ($)	Payback (years)
Efficient HVAC w/Setback	86,100	N/A
Electronic Ballast	16,500	1.45
T-8 Lamp Replacements	3,000	0.5
Occupancy Sensors	1,400	0.36
Smart Strip Surge Protectors	3,800	1.32
Computers (Sleep Mode and Shutdown)	1,600	N/A
Total	112,400	

Atlantic County Utilities Authority Energy Audit

The Atlantic County Utilities Authority (ACUA) energy audit involved two separate buildings, the Geo Building and the Operations Building. Both buildings had unique features that prompted student to learn more about energy audits and sustainability. The audit was lead by a Junior Civil & Environmental Engineering student, leading a team of engineering students from Civil & Environmental, Mechanical, and Electrical & Computer. All work was conducted by the students.

The ACUA Geo Building is the ACUA's main office building located in Egg Harbor Township, NJ. The Geo Building is approximately 22,000 ft^2 and was built in 1993. It was designed to be very energy efficient, using the technology available in the early 90's. For example, it incorporates daylighting and a Geo-thermal heating/cooling system with 22 heat pumps. Forty-one full-time employees and 7 part-time employees work in the building 5 days a week, year-round. These employees are careful to turn off their computers when they leave for the day. In 2007, the Geo Building consumed 519,440 kWh, which resulted in a $44,152 energy bill. One unanticipated finding of the energy audit involved the building's servers, which serve the needs of the entire ACUA. It was determined that it cost ~$18,000 to power the servers in 2007. One recommendation was to consolidate servers and, as appropriate, replace them with energy efficient models. As a result of the energy audit, possible savings of over $15,000 were found.

The ACUA Operations Building is part of a waste-water treatment plant facility located just outside of Atlantic City. The energy audit focused on the treatment plant's control room and offices, 20,900 ft^2 in all. The main section of the Operations Building was built approximately 30 years ago, with an addition added when the original structures was 15 years old. It is operated 24 hours a day, 7 days a week, year-round. There are 5 large wind turbines and multiple solar panel arrays on the waste-water treatment plant's grounds. In 2007, the entire waste-water treatment facility, including the Operations Building, consumed 18,889,253 kWh, which resulted in a $1,814,328 energy bill. Unfortunately, it was not possible to obtain separate energy consumption data for the operations building. As a result of the energy audit, of the operations building only, possible savings of over $20,000 were identified.

By following the energy audit recommendations, the ACUA can save upwards of $35,000 annually between their two buildings. Some of the recommendation made to save energy included switching to T8 light fixtures, relying on natural day-lighting, and incorporating thermostat setbacks. The ACUA is already a very environmentally aware organization and will most likely incorporate many of the energy saving recommendations. This will not only save them money, but will also reduce their carbon footprint and help preserve the environment.

Discussion

According to one of the student leaders, the energy audit clinic allowed him to learn how to work on a team with his fellow classmates and experience how a real engineering office operates. The teams had weekly meetings led by a team leader. Students experienced the real world application of their engineering education. This student indicated that he would use the information

obtained, and the communication and problem solving skills developed, for the rest of his life and to help make the world a better place.

All client reports and presentations were completed by the students. Professors ensured that the reports and presentations were "ready", but the students had to create and present them. This gave the student's a better understanding of the role of communication in engineering projects.

The goal of sustainable engineering is to provide the highest possible quality of life to people living now without negatively affecting the quality of life of future generations. There are a number of strategies that can be employed to meet this goal, including energy conservation and efficiency. By conducting energy audits on real buildings, students see the negative effect of unsustainable engineering (the inefficient buildings) and the positive effect of sustainable engineering (recommendations that improve building efficiency). Students experience sustainable engineering by practice and see the consequences of not following sustainable engineering practice.

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